This Article Appears In The June 2004 Issue Of Fire Engineering Magazine

The fire service is gasping for breath. Every year we witness the deaths of firefighters who run out of air after becoming trapped, caught, or lost inside a fire structure. A 10-year study by the U.S. Fire Administration identified this as the second leading cause of fatal injury to firefighters, accounting for 18.2 percent of firefighter fatalities.[1]

Despite a 54 percent decline in structure fires since the late 1970s, the rate of non-cardiac firefighter deaths inside structures has increased from 1.8/100,000 structure fires in the late 1970s to almost 3/100,000 structure fires in the late 1990s.[2] Firefighters today are almost twice as likely to die inside a structure fire as they were 25 years ago. In fact, over this same period, asphyxia/smoke inhalation was the leading cause of firefighter non-cardiac death inside fire structures, accounting for nearly 63 percent of the deaths. Smoke inhalation is not limited to firefighter deaths. From 1993 to1997, asphyxia was also the leading cause of severe firefighter injury, accounting for 21.3 percent of these injuries.[3]

THE EXIT TIME PROBLEM

Recent firefighter deaths in Houston, Texas; Phoenix, Ariz.; and Worcester, Mass., as well as many other cities, have shown that we do not always save enough air to get out. In fact, from 1993 to 2002, 86 firefighters died from asphyxiation inside structures.[4] Firefighters need more than 25 percent of the common 30-minute “rated” self-contained breathing apparatus (SCBA) for exiting; this is equivalent to a mere four to six minutes of air. This is not very much. What if you get lost or trapped? What if there is a structural failure? What if your exit becomes blocked? What if you get off the hoseline? What if the building you are in is a lot more mazelike and confusing than first anticipated? What if fire conditions change? What if …? Well, you do have four to six minutes. We know “what if”… happens. It happened in Houston, it happened in Phoenix, it happened to six firefighters in Worcester, and to countless others. These tragedies happen every year. They happen to smart, experienced, physically fit, adaptable, logical, sensible firefighters.

SITUATIONAL AWARENESS AND AIR MANAGEMENT

The National Fire Protection Association (NFPA) and the National Institute of Safety and Health (NIOSH) acknowledge that exit time, or escape time as some call it, is a serious issue facing the fire service. Yet, there has been a lack of tangible action to address this problem. Most solutions revolve around standards and recommendations that call for the fire service to improve “situational awareness” and “air management” procedures.

Situational awareness is a concept that has long been applied to the military, aerospace, and other high-risk fields. The Naval Aviation School Command defines

situational awareness as "the degree of accuracy by which one's perception of his current environment mirrors reality." Your reality is affected by your view of the situation, incoming information, and expectations and biases. Situational awareness can be reduced by things like insufficient communication, fatigue/stress, task overload/underload, and degraded operating conditions. It is easy to see how situational awareness is so easily applicable to our job.

Air management is closely related to situational awareness. It recognizes that we work in an environment that varies with every call and that the level of air consumed varies with each firefighter. Air management includes recognizing that the 25-percent low-air alarm is not adequate all of the time.

According to Lieutenant Stephen Bernocco of the Seattle (WA) Fire Department, the "Rule of Air Management" should be applied. It states that firefighters must be aware of how much air they have used and must manage the remaining air so they are able to leave a structure before their low-air alarm begins to sound.[5]

The key to air management is knowing that air needs vary according to the occupancy. The time needed to exit the structure should be part of our size-up, along with hoseline considerations and tool selection. However, this solution may be too idealistic. We work in complex environments; all the information we need to know to avert a tragedy may not be apparent. Buildings have secrets that are not always evident when we do our size-up. There are unknowns: fire loads, construction hazards, human error, and many others.

Advocates of the air management solution suggest that company officers, in addition to keeping their eye on the progress of the fire attack, rescue operations, smoke conditions, and other hazards, need to direct firefighters to stop and check their SCBA regulators at certain intervals and to keep the incident commander informed of the crew's air situation. It is not realistic or fair to expect firefighters assigned to task and tactical level work to monitor their air volumes while engaged in heavy work simply because the low-air alarm does not give adequate warning. Despite calls for the fire service to have better situational awareness and improved air-management skills, most firefighters rely on the low-air alarm to warn them that it is time to exit the hazard zone.

Proposed solutions, such as those presented above, are well intentioned, but I believe that they fall short. They are buzzword solutions that work well in the chief's conference room or at some NFPA meeting, but they are just concepts. Often, they play out differently on the fireground. Without implementation or *real* tools to improve situational awareness and air management abilities, these concepts are only boardroom solutions.

Regardless of which solution is adopted to address the exit-time problem, air management and situational awareness are still necessary components. However, air

management belongs at the strategic, not at the tactical or task, level. If NIOSH or the NFPA want to make a real impact on air management, their recommendations and standards should include a call for mandatory electronic management systems that allow a strategic command officer to monitor the air consumption of all firefighters in the hazard zone. Only then can air management be appropriately addressed.

MORE AIR?

We work in a dynamic environment. Yet, when it comes to air selection, we treat it as a static environment. That is probably because the real dynamic events are relatively rare in the grand scheme of things. When they do occur, we are usually not fully prepared for the "what-ifs," and our low-air alarm is not set to allow enough time for us to exit larger structures. The commonly held belief is that four to six minutes of warning we get from a 30-minute rated air bottle will get us out.

The logical solution, and one often proposed, is that we need more air. Bigger bottles are available—45- and even 60-minute bottles. But the fire service still predominantly uses the 30-minute rated bottle. Why don't we all just accept the reality and give ourselves more air?

The argument against it goes something like this: More air in a bigger bottle means more time in the hazard zone. More time in the hazard zone means more work stress and firefighters' going deeper into a structure. More work stress means more injuries and a higher cardiac arrest potential. The deeper you get into a structure, the more likely you are to get into trouble, run out of air, and die. Therefore, do we really want more air?

The solution is complicated by an outdated rule that governs how much air a firefighter can have to exit. This is not a rule we imposed on ourselves. It is Federal Regulation (42 CFR part 84), which applies to all SCBA users, firefighters and non-firefighters, and predates almost anyone in the U.S. fire service. The rule states the following:

> Each remaining service-life indicator or warning device (that's low-air alarm to you and me), shall give an alarm when the remaining service life of the apparatus is reduced within a range of 20 to 25 percent of its rated service time.

The flaw in this rule is that it has an upper limit of alarm (25 percent). By limiting the alarm period to this range, an SCBA's required alarms cannot be made to warn the user before 25 percent of the remaining service time. This rule does not meet the needs of the fire service.

This stipulation predates the adoption of 42 CFR 84 in 1995. In fact, the 25 percent upper limit was in place before 1960. Although it is difficult to know for certain the rationale for including an upper limit in the rule, Sam Terry, who has worked for federal

regulatory agencies governing respirators for more than 42 years, has speculated that the 25-percent stipulation reflects the technology available at the time of the original regulations.

Many of the foundations for such earlier decisions have eroded in the face of technological advances and strategic and tactical changes that make it possible for today's firefighters to go more deeply into a structure than regulators at that time could have anticipated.

The original regulation was rendered outdated by the following changes:

- Early SCBA cylinder technology limited bottle pressure to 1800 psi, resulting in limited air volume that could be reasonably carried. The result was a compromise in exit time, to gain the maximum benefit of the SCBA for firefighting purposes. Today's air bottles do not pose this same limitation.
- Prior to the 1960s, firefighting strategy consisted of limited offensive firefighting. Today, deep offensive firefighting is the norm.
- Firefighting protective clothing has evolved considerably over the years, allowing for much deeper offensive firefighting. This deeper penetration can result in inadequate air reserves for exit.
- The large and complex structures of today (both vertical and horizontal) were uncommon at the time this regulation was established. These structures may require more time for firefighters to exit and firefighters are more likely to become disoriented in them.

The last three changes place firefighters in greater danger than in years past. In fact, today's firefighters are more than twice as likely to be killed while fighting a fire in a nonresidential structure than in a residential structure.[6] More than ever, we need additional time for exit.

DEALING WITH THE PROBLEM

The question we keep asking ourselves is, do we really want more air? After all, more air means more work stress and deeper building penetration. Many more injuries may be associated with more air. The result of this debate is that we don't move forward on this issue.

We know that we need more exit time. The problem with the current regulation is that the only way to increase exit time is to increase bottle size, which in turn increases time in the hazard zone [25 percent of a variable figure (30-, 45-, 60-minute rated bottles)]. The fire service has shunned this solution because of work stress and depth-entry concerns. As a result, many fire departments in the United States and Canada have chosen to keep a short exit window in favor of a short work period.

The federal regulation must be changed. We can have more air without having to compromise work stress levels or jeopardizing safety by going too deep into a structure. We need to be able to get out alive. *We do need more air, but we need it for exiting.*

The exit time problem is a fire service issue. There is a lot of pressure to come up with a solution for dealing with firefighters' running out of air in an immediately dangerous to life and health (IDLH) environment. Ideas such as a separate escape bottle (similar to that used for haz-mat and confined-space entry), combination open-circuit/closed circuit SCBA, and powered air purifying respirators (PAPR) that are integrated into an SCBA have all been put forward. These solutions are nothing more than imagination gone wild. The problem is that we do not carry enough air for exit because we set the alarm too late. The solution is as simple as setting the alarm earlier.

If we raise the point of alarm on our SCBA, we can open the exit window while maintaining an effective work period. We have also opened the windows of rapid intervention, self-rescue, and, if need be, victim rescue. The current regulation does not leave a lot of room for these things once the alarm begins to sound. This is not reasonable.

The following change should be implemented for fire service users of SCBAs:

> Each remaining service-life indicator or warning device shall give an alarm when the remaining service life of the apparatus is *reduced to no less than 25 percent of its rated service time.*

This may mean that a larger bottle is more appropriate. For instance, if you are currently using a 4500-scf (square cubic feet) of air 30-minute rated SCBA bottle, and you are happy with the work period provided prior to alarm, you may want to take a 45-minute rated bottle and adjust the alarm to 50 percent. You are keeping your hazard zone time exactly where you want it, 3,300 scf of air, virtually the same as your existing 30-minute bottle. Now, your work stress and depth-entry concerns are the same, but you have tripled your exit window from four to six minutes (1125 scf) to 12 to18 minutes (3300 scf). Your work period is unchanged. (See Page 11 "TIME IN A BOTTLE")

The recent addition of a heads-up display (HUD) in the SCBA facepiece that gives a 10-second visual alert at 50 percent is a step in the right direction, but it does not go far enough in addressing the exit time problem. The HUD alarm is of short duration and does not alert the entire crew that a member has reached the halfway point. Simply put, it's not annoying enough.

Serious consideration needs to be given to the continued use of the 30-minute rated SCBA bottle. Its place in the fire service toolbox must be questioned. The fire service needs to look closely at the real air needs of today. This has not been done, generally because it is too variable. Air consumption varies with the climate you work in, the

structures you enter, and firefighters' physical abilities; it would be impossible to come up with some magical number that would work for all fire departments all of the time. That's why a boilerplate solution is inappropriate.

But, we are talking about life and death. Shouldn't we be packing for the less likely scenario instead of the most common one? The air supply you carry on your back for structural firefighting should be based on a reasonable work period plus a reasonable exit period plus a margin of error.

SCBA Air Volume = Work Period + Exit Time + Margin of Error for Self-/RIT Rescue

The problem with hard-and-fast rules is that they do not apply to everybody or every situation. What may be right for the Fire Department of New York may not fit the operational parameters of the Columbus (OH) Fire Division. A fixed percentage of alarm regardless of the air cylinder volume does not fit the needs of all users.

It is not the responsibility NIOSH or the NFPA to determine these needs. Minimum standards should be established, and individual fire departments should be allowed to determine if their own needs lie above these minimum standards. Simply put, this is an issue of local autonomy.

The priority that should be used to determine when the low-air warning should be set to alarm should be invariable. The low-air alarm should sound at the end of the "work period" volume; all remaining air is for life safety. Air for working, although important (it's the reason we are there), should not be given a higher priority than air for exit or margin of error (the "what ifs"). Remember our priorities: life safety first, including our own!

Fire Service Priorities and Air Allocation

PRIORITY	AIR ALLOCATION
Life Safety - Firefighter	Exit Time & Margin of Error
Life Safety - Victims	Work Period & Exit Time
Property Conservation	Work Period
Incident Stabilization	Work Period

TOO MUCH AIR?

The fire service has largely rejected the use of larger SCBA bottles because these bottles appear to provide more air than we need. This may be true most of the time, but does it make sense to carry less than you may need just because the odds are in your

favor? There may be a low risk of getting caught short on air, but the consequences can be deadly. Even though we put out 90 percent of our fires with less than 500 gallons of water, we still carry 500 to 1,000 gallons of water on our trucks. It's a matter of preparing for that 10 percent of the time when we may need more. There is a reason that we are twice likely to be killed while operating at nonresidential structures; Most firefighters are wearing a residential air bottle.

The main argument against increasing exit time is that more air will only lead to some firefighters' ignoring their low-air alarm. This is probably because of our "can-do" nature. Many firefighters may feel compelled to use every last drop of air they carry on their back before taking a break. This reflects the need for behavior modification through training and enforcement.

The issue of alarm abuse is not a federal regulatory issue. It should not even be an NFPA issue. These agencies develop minimum standards and recommendations. Alarm misuse and abuse should be dealt with as a training and command issue at the local level.

The additional exit air proposed by this solution is there for the unusual situation; it is not intended for routine use. There may be times when it is acceptable to operate with an alarm sounding. This should be the exception, not the rule. All alarms sounding without crews exiting should be investigated.

The fire service has grown accustomed to the false alarm. Whether from a residential high-rise at two in the morning or our always-sounding PASS devices, the fire service has learned that these alarms are seldom warnings of "the real thing." One alarm that rarely malfunctions is our SCBA low-air alarm. It is rather simple by design; when it sounds, it is time to go. Most firefighters probably don't think about just how little time they have left when this alarm sounds; fortunately, most have not had to experience running out of air when it really mattered. Low-air alarms must be heeded!

TOO MUCH WEIGHT?

In fact, when SCBA were first introduced to the fire service, the decision was in favor of less air and reduced weight and bulk (technology was new; bottles were still relatively large, heavy, and of low volume). In the 40-plus years since, we, hopefully, have learned that the earlier decision, although appropriate back then, clearly does not meet today's needs. Furthermore, the original justification (lower weight and air volume) does not match today's technological reality. Today, we can carry more air at a significantly reduced weight. We need to consider basing our air choices on our real air needs. Even if the result is some additional weight and bulk, it will not come close to the weight and bulk of yesterday's SCBA. The weight of a 30-minute rated SCBA has been reduced by as much as 50 percent over the past 25 years.

FIREFIGHTER DEATHS AND THE CHAIN OF EVENTS

To say that firefighters died simply because they ran out of air might be oversimplification and unjust. Most firefighter injuries and deaths usually have several contributing factors, or have been triggered by a chain of events. More than we probably realize, we sometimes break this chain. One firefighter misses something, but five right behind him catch it and alleviate it. In rare cases (3/100,000 structure fires), the chain is not broken and someone dies. If we can remove one or more of the contributing factors, we would be left with a typical working fire--not everything goes perfectly, but we all go home.

It is the common contributing factors, the ones we see again and again, that have the real potential to save firefighters' lives. Reviewing NIOSH investigations of 68 incidents occurring between 1997 and 2002 in which at least one firefighter was killed at a structure fire, reveals that 44 firefighters in 33 incidents died from asphyxiation. Running out of air was a contributing factor in each of these deaths. If we can alleviate this factor, perhaps we can reduce the number of firefighters who die inside structures.

RAPID INTERVENTION IS NOT A SOLUTION

Sending firefighters time and time again to do a job, knowing that they may not have what they need for the trip back, is unacceptable. Our usual reaction to this realization has been to better prepare ourselves to respond to a report of a lost firefighter. We dedicate incredible time and resources to ensure that we are ready to intervene and save the day.

There is little question that rapid intervention is a necessary and successful element of fireground operations, but for rapid intervention to be even more successful, we must ensure that all firefighters have enough air so they can be savable when the rapid intervention team (RIT) gets to them. In a series of more than 200 drills that evaluated the effectiveness of rapid intervention conducted by the Phoenix Fire Department, it was found that it took an average of eight to nine minutes to locate a downed firefighter. (This study is a must read for anyone concerned about firefighter survival). [7] This does not match up well with the limited volume of air we carry into a structure. Are the RIT members going to be able to give the troubled firefighter more air and effect a removal before they get into trouble themselves?

Rapid intervention has been a great addition to the repertoire of the modern firefighter. Firefighter fatalities inside structures have been on the rise over the past 25 years. Without rapid intervention, how much worse would this figure be? Every firefighter should be proficient in locating and removing firefighters in trouble. However, we must not forget that rapid intervention, by nature, is reactionary. If we really want to reduce

firefighter fatalities in this country, then we must stop being reactionary when it comes to the cause of death. We must be proactive.

IMPLEMENTING CHANGE

By now you should be asking yourself, "Why is it that we accept a remaining service indicator that alarms at 25 percent?" Why is four to six minutes exit time acceptable? To start with, NIOSH is a government agency that regulates all respirators for all users, not just the fire service. Its rules are often blind to the needs of individual user groups. It may not be aware of a user group's needs, at least not until that group tells the agency.

You now have an opportunity of make our needs known to NIOSH by participating in the rulemaking process for changing Federal Regulation 42 CFR part 84 *so that the upper limit (25 percent) of the alarm time is removed.* The rulemaking process, which includes public comments, is necessary for formulating, amending, or repealing a regulation. A rulemaking *docket,* which serves as the official repository for the collection of documents or information related to this particular regulation, has been established. *This should be a call for action for the fire service*. We should not stand by and let an antiquated federal regulation that is costing us firefighter lives continue to be imposed on us. Take the opportunity to go on record.

PUBLIC COMMENTS, RULEMAKING PROCESS, 42 CFR, PART 84

Public comment can be made on this rulemaking docket by any of the following methods.

1) Go to **www.timetoexit.com**; follow the link "submit comment."
2) E-mail the NIOSH Docket office: **niocindocket@cdc.gov**
3) Write to the NIOSH Docket Office: NIOSH – 034; Robert A. Taft Laboratories; Mail Stop 34, 4676; Columbia Parkway, Cincinnati, OH 45226.

Include the reference topic SCBA ESLI and Docket Number NIOSH-034 on all submissions.

One can also monitor the *Federal Register* website to see when the docket is opened for public comment. There will be a direct link for commenting on the rulemaking.

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Situational awareness, air management, and rapid intervention do not provide a great enough margin of error when they fail. Likewise, the reflex time associated with rapid intervention puts a downed firefighter at great risk of exhausting his/her air supply before the RIT arrives. Like any high-risk/low-frequency event, a greater safety margin should be adopted.

The firefighter exit window must be opened to better protect firefighters against the hazards associated with the increasingly large structures being built today and the technology that allows firefighters to go deeper into these structures.

Building a greater safety margin into our exit time would also result in "opening the windows" for self-rescue and RIT rescue. Approval of the proposed change in the NIOSH regulation would expand the "exit window" for firefighters.

Endnotes

1. *Firefighter Fatality Retrospective Study 1990-2000*, U.S. Fire Administration, Apr. 2002, 23.
2. Fahy, Rita F., *U.S. Fire Service Fatalities in Structure Fires 1977-2000*, NFPA, July 2002, 2.
3. Karter, Michael J. Jr., *Patterns of Firefighter Fireground Injuries*, NFPA, Feb. 2000.
4. Fahy, Rita F., Obtained through special research conducted by the NFPA, Dec. 2003.
5. Steve Bernocco, et al., "Train in the Rule of Air Management," *Fire Engineering*, Apr. 2003, 57.
6. LeBlanc, Paul R, and Rita F Fahy, *Firefighter Fatalities in the United States – 2002*, NFPA, July 2003, 4.
7. Kreis, Steve, "Rapid Intervention Isn't Rapid," *Fire Engineering*, Dec 2003, 56.

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TIME IN A BOTTLE

When comparing SCBA cylinders, look at the bottle's rated capacity (volume). An SCBA cylinder's rated pressure does not give any indication of the volume of compressed air it will hold. The following charts show estimates of hazard zone time vs. exit time for 25 percent and 50 percent low-air warnings.

25% Remaining Service-Life Indicator *(Current Rule)*					
Rated Time	**Air Volume**	**HZ* Volume**	**Avg. HZ Time**	**Exit Volume**	**Avg. Exit Time**
30 minutes	4500	3375	12-18 min	1125	4-6 min
30 minutes*	6000	4500	16-24 min	1500	5-8 min
45 minutes	6600	4950	18-27 min	1650	6-9 min
60 minutes	8800	6600	24-36 min	2200	8-12 min

Air volumes are measured in square cubic feet of air (scf).
HZ= Hazard Zone. Average times are estimates based on .218-.327 seconds/scf; actual time will vary with user
* Uncommon 3,000-psi 30-minute rated SCBA

50% Remaining Service-Life Indicator *(Proposed Variable Rule)*					
Rated Time	**Air Volume**	**HZ Volume**	**Avg. HZ Time**	**Exit Volume**	**Avg. Exit Time**
30 minutes	4500	2250	8-12 min	2250	8-12 min
30 minutes*	6000	3000	11-16 min	3000	11-16 min
45 minutes	6600	3300	12-18 min	3300	12-18 min
60 minutes	8800	4400	16-24 min	4400	16-24 min

Air volumes are measured in square cubic feet of air (scf).
HZ= Hazard Zone. Average times are estimates based on .218-.327 seconds/scf; actual time will vary by user.
*Uncommon 3000-psi 30-minute rated SCBA

An SCBA cylinder's rated time in minutes does not accurately reflect the amount of time most users doing firefighting tasks can expect to be breathing air. The time estimates are considered generous when compared with real-world experience with SCBA. Most users are likely to be on the low end of the range.

A recent study conducted by the Phoenix (AZ) Fire Department revealed that most users should expect to get between 16.5 to 18.5 minutes of air before their low-air alert activates. Phoenix uses a 3000-psi, 6000-scf 30-minute rated bottle. This bottle is somewhat of an anomaly when it comes to air bottles. Most of the U.S. fire service uses a 4500-scf, 30-minute rated air bottle. The Phoenix 30-minute rated air bottle is much closer to a true 30-minute rated bottle than what most other users carry on their backs. The 6000-scf, 30-minute rated bottle begins to alarm after 4500 scf of air has been exhausted, when most other 30-minute rated bottles are empty.